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ABSTRACT

This paper deals with the primary processes of cognition in fifth- and sixth-grade children; i.e., how children this age interpret what they see and hear, how they remember it, and how they reason and solve problems. Designed to provide background information for the staff of the Skills Essential to Learning Television Project (a multi-level series of video and print resources for classroom use), the paper begins with an extensive review of cognitive development as theorized by Piaget and Bruner, and qualitative changes in the ways that older elementary school children actually respond to cognitive tasks. A discussion of cognitive skills examines Gagne's logical, analytical approach to teaching the skills. A look at the acquisition of verbal information includes methods of organizing written materials to maximize retention of the information. Research on Ausubel's "advance organizers" is presented along with other research on the meaningful coding of names and labels and the use of imagery. An examination of cognitive strategies and divergent thinking specifically reviews the research concerning problem solving with fourth- and fifth-grade children. A summary and examination of the study implications are included. Seventeen references are listed. (LMM)

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COGNITION IN FIFTH AND SIXTH GRADE CHILDREN

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The working paper reported here was written by Candace S. Garrett and Patricia M. Marshall of the University of New Mexico, for the Skills Essential to Learning Television Project, of the Agency for Instructional Television.

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February 1977

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COGNITION IN FIFTH AND SIXTH GRADE CHILDREN

This paper deals with the primary processes of cognition in fifth and sixth grade children: how children this age interpret what they see and hear, how they remember it, and how they reason and solve problems. It presents a practical review of what is currently known about cognition. The first and most extensive section deals with cognitive development as theorized by Piaget and Bruner. Since their theories indicate dramatic qualitative differences in the way children of different ages come to know the world, this section also includes descriptions of the qualitative changes in the ways that older elementary school children actually respond to cognitive tasks.

The second section is concerned with cognitive skills and examines Gagne's logical, analytical approach to teaching the skills. Since Gagne makes no differentiation between the potential cognitive skills of older and younger children and, indeed, might argue with Piaget that differences in performances with age are quantitative rather than qualitative in character, his approach applies to learners of all ages.

The third section deals with the acquisition of verbal information. It presents methods of organizing written materials to maximize retention of the information. Research on Ausubel's advance organizers is presented along with other research on the meaningful coding of names and labels and on the use of imagery.

The fourth section discusses cognitive strategies and divergent thinking, looking specifically at research on problem solving with fourth and fifth grade children.

The last section is a summary with implications for teaching problem-solving to fifth and sixth grade children.

Cognitive Development

Since most states require children to be 5 years old to enter kindergarten or 6 years old to enter first grade, fifth and sixth grade children will be generally between the ages of 10 and 12. This developmental period is generally referred to as late childhood or preadolescence. The latter term will be used in this discussion. Some of the older children in this target group will have entered puberty and will be called adolescents; most of these children will be girls since on the average females generally enter puberty earlier than males by 1½ or 2 years (Longstreth, 1974).

Several theorists have described the development of cognitive competence in children. Two theorists often cited in conjunction with educational concerns are Piaget and Bruner.

Piaget's theory of intellectual development is a stage theory. His four basic invariant stages include: sensorimotor, preoperations, concrete operations, and formal operations. Each stage is built on the previous one but is qualitatively different from it. That is, at each stage of development, the way in which the child structures what s/he experiences and the ways in which s/he verifies the truth of his/her own thinking about the world are quite different. According to Piaget, the child is an active participant in his/her own development. The causes of intellectual development include maturation; experience physical experience to acquire knowledge of the physical properties of objects and spatial relations, and logicomathematical experience to acquire

knowledge of the results of actions on objects; and the social environment, for example, language, direct instruction, models to imitate (Rohwer, Ammon, & Cramer, 1974). Briefly stated, Piaget's theory suggests that the environment can slow intellectual development if the minimum necessary physical and social conditions are not met, but that it cannot accelerate development through enrichment (Piaget in Lavatelli & Stendler, 1972). However, other cognitive theorists who subscribe basically to Piaget's theory believe that through careful manipulation of the environment intellectual development can be accelerated (Rohwer, Ammon, & Cramer, 1974).

Bruner's theory is quite complementary to Piaget's. Bruner however emphasizes the mode of children's cognitive representation of the world. In early childhood, the enactive mode is the only mode whereby the child can represent his/her world. This mode is representation through action. As children develop cognitively, the iconic mode also is available for their use. This mode is perceptual in nature, following Gestalt principles. As children approach adolescence, the symbolic mode begins to develop. With this mode, children are able to use language to represent the world symbolically. A child can use the latest mode s/he has developed as well as all prior modes (Bruner, 1971). According to Bruner, the acquisition of knowledge and the cognitive representation of the knowledge is an active process (Bigge, 1976). The environment can speed up or slow down intellectual development (Bruner, 1971).

Since these theories are basically complementary, the following description of children in the target areas is organized around Piaget's stage formation theory but includes relevant aspects of Bruner's theory as well as descriptions of how children of these ages actually respond to cognitive problems.

Those few 11- and 12-year-olds who have entered puberty have also probably entered the stage of formal operations (Rohwer, Ammon, &Cramer, 1974). They are well

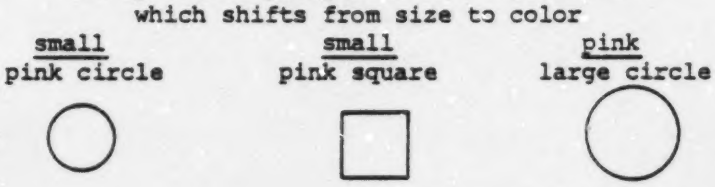
able to use the enactive and iconic modes of representation and also are starting to use symbolic representation, (Bigge, 1976). However, most children ranging from age 7 to 11 or 12 are in the stage of concrete operations (Kohen-Raz, 1971), although some children start at age 5 and others not until 8 (Rohwer, Ammon & Cramer, 1974). Thus, most fifth and sixth graders will be at the end of this stage.

The thinking of children at this stage is different from that of younger children. Concrete operational children understand that certain aspects of an object or set of objects are invariant regardless of physical transformations of the objects. For example, a concrete operational child will understand that the amount of clay in a ball remains the same no matter what shape the clay is rolled into. This operation is called conservation of quantity and occurs on the average at about 7 years of age. Conservation of quantity is possible because the child is able to reverse operations mentally. S/he knows, without manipulating the clay, that the new shape can be rolled back to the original shape and thus the quantity remains unchanged. Prior to this stage, children cannot mentally reverse operations (Phillips, 1969). Children of 11 and 12 years of age are generally well-versed in this aspect of concrete operational thought and, indeed, may find the reasoning of the preoperational child amusing. In addition, children who have attained this stage are able to consistently group sets of objects according to any one of several different classification schemes. On the other hand, preoperational children tend to group according to pictorial or representational meaning; they are inconsistent in grouping, often changing classification systems in the middle of the grouping (Rohwer, Ammon, & Cramer, 1974). For example, a set of objects may include paper shapes that are pink or blue, squares or circles, and big or little. A preoperational child may start to sort the shapes into two piles based on size. S/he may put a small pink circle in one pile, then a small pink square in the same pile, and

then forget that s/he originally decided to sort on size and so add a big pink circle for a color sort (see Figure 1). These children chain from response to response rather than continuing an overall pattern (Rohwer et al., 1974).

FIGURE 1

Example of a preoperational child's sort which shifts from size to color



Concrete operational children can sort on all three different attributes, staying consistently with one scheme until a sort is finished.

Concrete operational children are also able to understand part-to-part and part-to-whole operations, including class inclusions. They are able to make a quantitative comparison between a subclass and a higher-order class. For example, if you show such a child a set of wooden beads where most are brown but a few are yellow and ask "Are there more brown beads or more wooden beads?" a concrete operational child (who understands this operation) will reply "More wooden ones" (see Figure 2). A preoperational child will reply "More

FIGURE 2

Wooden beads used in a class inclusion Piagetian task

brown ones." S/he cannot do the operation because s/he cannot attend to the subclass (brown beads) and the higher-order class (wooden beads) at the same time, so the child apparently turns the question into "Are there more brown beads or more yellow beads?" and answers "More brown ones." The concrete operational child can think about the beads as brown and wooden at the same

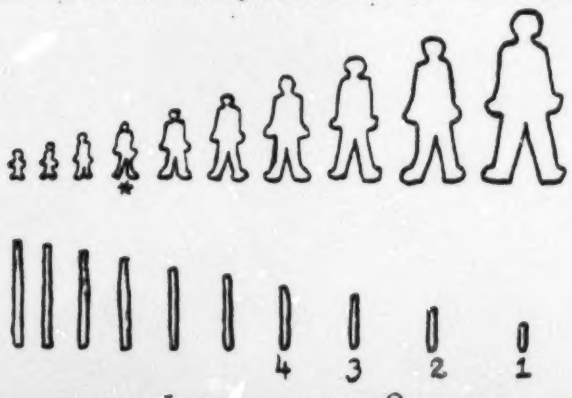
time and can compare them quantitatively (Phillips, 1969).

This conceptual inability with class inclusion is often shown in the difficulty younger children have in naming fractions. Preoperational children will often choose as denominators the number of objects left over after the target set has been "used up." For example, the fractional name for three shaded triangles out of a total of five is often written by the child as 3/2 instead of 3/5 because the preoperational child feels that the three triangles in the numerator have already been taken and are no longer available for the denominator. Vestiges of this kind of thinking are still found in some fifth and sixth graders.

A concrete operational child is able to consider two or more characteristics of the same object at the same time, as in the above bead example. An early preoperational child cannot do this at all while a later preoperational child can only do this with characteristics that are similar (Bruner, 1971; Rohwer, Ammon, & Cramer, 1974). For example, one Piagetian problem asks children to match a set of dolls that vary greatly in height with a set of sticks that vary in length but not as much as the dolls vary in height. Late in the preoperational stage, a child can do this problem if both the dolls and the sticks are arranged in the same order (e.g., from little to big). The child cannot do the problem, however, if the dolls and sticks are arranged in opposite orders (e.g., dolls from little to big, sticks from big to little—Figure 3).

FIGURE 3

A Piagetian task involving relative size and seriation



When asked "What stick will this doll (*) take?", the reversed order forces the child to consider both the relative size of the objects as well as the number of objects at once. Often, preoperational children will mechanically count the dolls up to, but excluding, the reference doll and then count the same distance from the other end of the series of sticks arriving at number 3 instead of the correct one (4) as their answer. The concrete operational child can do both of these problems (Phillips, 1969).

Concrete operational children have decentered enough to be able to mentally take someone else's view without having to move physically to his/her position. In addition, the children are able to shift viewpoints back and forth between their own and that of another person in social relations. They have started to understand rules as social conventions that can be changed by agreement of group members; preoperational children think that rules are absolute and unchangeable (Rohwer, Ammon, & Cramer, 1974).

Concrete operational children are starting to understand the concept of spatial and natural laws. For example, they can apply the principle that the surface level of water in closed bottles is always horizontal to the ground. If shown a corked bottle half full of water and asked to indicate where the water level would be if the bottle were tilted, a preoperational child would draw the line parallel to the bottom of the bottle regardless of the tilt of the bottle. A concrete operational child would draw the water line parallel to the ground regardless of the tilt, thus matching the reality of the world (Phillips, 1969). Although this is the classic Piagetian description and is found several places in the literature, a surprising number of college students (about 50%) do not demonstrate an understanding of this principle when asked to apply it correctly in this type of situation (Thomas, Jamison, & Hummel,

1973). This kind of misconception about physical laws undoubtedly exists in some 11- and 12-year-olds as well.

Concrete operational children construct time and movement to match adults' perceptions. These children are able to follow transformations involving both distance and time simultaneously; preoperational children concentrate on one or the other and thus have some strange notions. For example, if a preoperational child watches an adult simultaneously move a blue toy car 12" and a yellow toy car 6" in the same amount of time, the child will insist that it took longer for the blue car to move than for the yellow car. A concrete operational child says that they both took the same time; the longer distance traveled by the blue car does not convince the child that the blue car also traveled for a longer time (Phillips, 1969). Similarly, concrete operational children start to become more quantitatively oriented. For example, they can correctly sequence historical events as well as accurately estimate lengths of time, such as a minute (Rohwer, Ammon, & Cramer, 1974).

A child who has attained or completed the concrete operational stage can engage in the following operations: class inclusion, reversibility, some decentering, and taking another person's physical or social view, among others (Phillips, 1969). They can discriminate and generalize accurately, use symbols to mediate, and create and use hierarchies (Kohen-Raz, 1971). They perceive objects accurately and realistically (Rohwer, Ammon, & Cramer, 1974). Table 1 contains examples of the development of understanding of the physical world.

However, concrete operational children understand only what is real and has some sort of physical referent, not what is abstract or involves hypothetical concepts. In the stage of formal operations, which some of the target children may be starting, the adolescent is able to operate on operations, that is, to think about abstract possibilities (Bruner, 1971; Rohwer, Ammon, & Cramer, 1974). Adolescents can think about experiments and form hypotheses about the outcomes before

TABLE 1

EXAMPLES OF DEVELOPMENT IN UNDERSTANDING THE PHYSICAL WORLD[1]

PERIODS OF DEVELOPMENT	AREAS OF DEVELOPMENT			
	OBJECTS	SPACE	TIME AND SPEED	CAUSALITY
Sensorimotor	Object permanence	Unified space, independent of particular actions; detour behavior	Immediate temporal successions independent of actions	Initial externalization of causes
Preoperational	Intuitive rules regarding amount, weight, etc.	Intuitive rules regarding length, height, distance	Localized time; rule of passing; extended time series	Animism; artificialism
Concrete operations	Conservation of amount, weight, etc.	Conservation of length, etc.; projection of straight line; measurement of space; use of coordinates	Unified time; measurement of time	Inanimate external causality; noncontradictory causal explanations
Formal	Conservation of exterior volume; understanding of density	Proportionality with regard to space; ability to conceive of hyperspace	Proportionality with regard to time, speed	Isolation of causes through scheme of "all other things being equal"

[1] From Rohwer, Ammon, & Cramer, 1974.

they physically attempt the experiments. If the actual results of the experiments do not support their hypotheses, they can then change their ideas by determining where their reasoning was in error. For example, suppose the experiment of interest concerns floating objects. Concrete operational children will try to determine some principle based on two or more of the observable physical characteristics of the floating bodies, perhaps size and weight. This approach will not work, and they will not understand what is wrong. A formal operational adolescent will try an operation, such as considering density, on these two characteristics. S/he may then compare the density of the floating object to the density of the water that the object displaced and hence discover the principle of floating objects. A formal operational adolescent can consider several hypotheses, test them, and alter them on the basis of the test results. S/he is a scientist. The concrete operational child is not (Phillips, 1969).

Adolescents are capable of understanding complex situations and the relations presented in problems. They make fewer accidental assumptions caused by attending to irrelevant parts of the problems or by making incorrect logical

assumptions. For example, a preadolescent may decide that if the problem says that all of the children in group X are also in group Y, then everyone in group Y is also in group X. The child is making a logical error which may cause him/her to solve the problem incorrectly. An early formal operational adolescent is much less likely to make logical errors. However, early adolescents still have somewhat limited attention spans, and forget important aspects of the problem if there are too many elements or operations involved in reaching a final solution. Hence, they should be encouraged to use memory aids, such as writing down partial solutions, using pictures to help in the solution, and so on (Kohen-Raz, 1971).

Based on these cognitive characteristics of preadolescents and adolescents, various recommendations concerning educational programs and methods can be made.

In general, preadolescents will apply concrete operations to many content areas, although some may occasionally use preoperational thought while others, operational thought. Kohen-Raz (1971) indicated that formal reasoning is used earlier in mathematics and the physical sciences than it is in biology and the humanities. According to Frankenstein (in Kohen-Raz, 1971), the learning tasks for preadolescents should involve fostering abstract cognitive expansions (i.e., moving them toward formal operations) based on their accurate perceptions of the physical and social worlds. Learning also should involve additional decentering of the adolescent from his/her own personal view (Kohen-Raz, 1971).

Preadolescents can assimilate or absorb information that requires mental expansion of a realistic sort, even if it is independent from his/her own personal experiences. For example, they can understand "...living conditions in a remote country; the patterns of a historic event; the physical, biological, and anatomical structure of objects" (Kohen-Raz, 1971, p. 148). They are able

to assimilate abstract concepts in the context of concrete materials. They have a well-developed language system available for symbolic use that helps free them from physical presentations (Bruner, 1971; Kohen-Raz, 1971).

As children move into formal operations, many principles and operations of mathematics become available for learning that cannot really be understood at any previous level. Since formal operational adolescents can operate on operations and can understand concepts that do not have tangible physical referents, they can learn to manipulate fractions, use exponents and roots to solve algebraic equations, understand negative numbers, and grasp the laws of Euclidean geometry. Since preadolescents and adolescents are able to quantify and order time, history becomes understandable. Since they are able to decenter enough to start to take others' views, geography and culture are understandable at a conceptual as well as a recall level. Preadolescents are often aware of the social and cultural problems surrounding them and are willing to state their opinions complete with reasons. They are less dogmatic and less extreme in their views than are preoperational children (Garrett, Ein, and Tremaine, in press). Since adolescents can engage in logical scientific experiments, many more types of scientific principles are open (Kohen-Raz, 1971).

Cognitive Skills

Robert Gagne (1974) has written extensively on an approach to learning which emphasizes a logical assembly of the psychological units of the subject matter to be learned rather than the psychological stages of the learner described by Piaget and Bruner. He lists five levels of learning into which any intellectual skill may be categorized. They are:

HIGHER ORDER RULES	Putting together simpler rules to make more complex ones; e.g., finding the area of a parallelogram by subdividing it into a rectangle and two triangles, using area rules for them, and adding the results.
RULES	Applying a class of procedures to a class of things; e.g., changing adjectives to adverbs by adding LY; finding the area of a rectangle; subtracting one number from another.
CONCEPTS	Identifying simple classes of objects, object qualities, or relations; e.g., animals, stars, jagged, circular, cowardly, over, behind, middle.
DISCRIMINATIONS	Detecting distinguishing features among objects; e.g., red differs from yellow; soft from rough; b from d.
SIMPLE LEARNINGS[1]	Stimulus-response type learnings; e.g., associating an object with its name.

These levels are hierarchical, each succeeding level being more complex and encompassing the one below it. He uses this hierarchy in order to subdivide any unit of material to be taught into its component skills, thereby enabling a curriculum planner to determine the prerequisite skills for learning the unit. For example, if a person wanted to teach a group of sixth graders how to find the sum of n terms in a number series, the task would first be analyzed into its subskills (see Figure 4).

Starting from the bottom, the discriminations and simple learnings included in the circles are such things as being able to identify and discriminate among the symbols a,b,c,...1,2,3,...; +,X,=,( ), (fraction notation) as well as being able to associate numbers of objects with numerals (counting). Necessary concepts for this task are spatial concepts--right, left, above, below; vertical and horizontal (to be used in assigning letters and subscripts to the numbers in the series); and sum, product, dividend, and equality.

[1] Gagne actually breaks these simple learnings into even smaller units but they need not be considered in this context.

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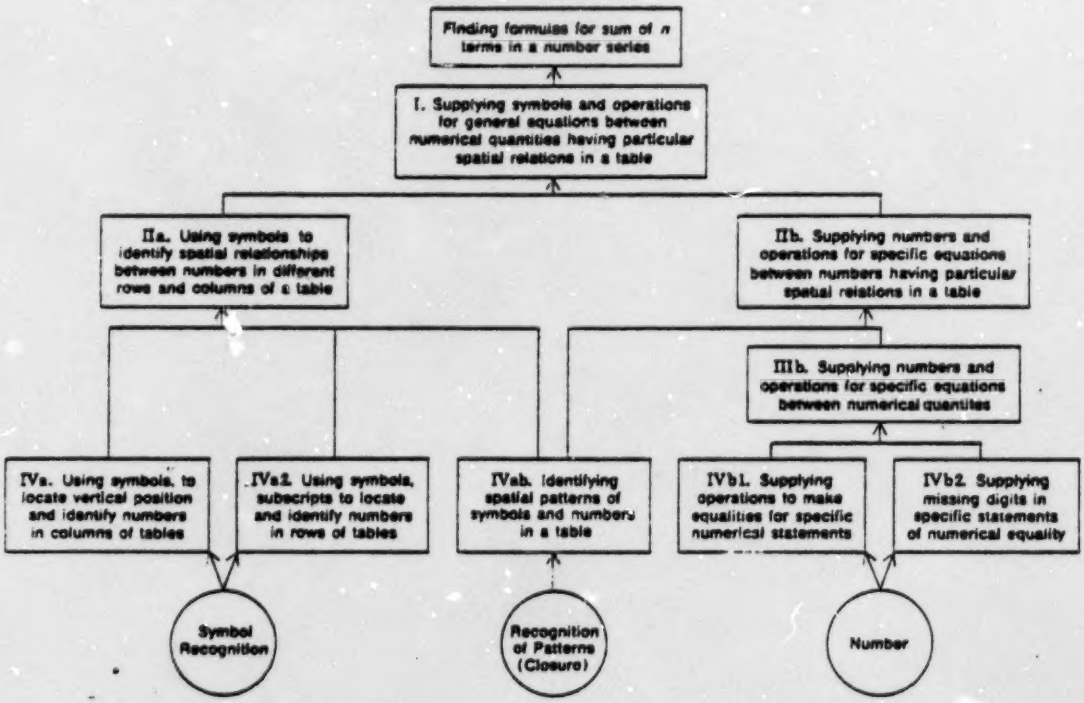
FIGURE 4

Hierarchy of knowledge for the task of finding formulas for the sum of N terms in a number series


Finding formulas for sum of n terms in a number series
I. Supplying symbols and operations for general equations between numerical quantities having particular spatial relations in a table
IIa. Using symbols to identify spatial relationships between numbers in different rows and columns of a table
IIb. Supplying numbers and operations for specific equations between numbers having particular spatial relations in a table
IIIb. Supplying numbers and operations for specific equations between numerical quantities
IVa. Using symbols to locate vertical position and identify numbers in columns of tables
IVa2. Using symbols, subscripts to locate and identify numbers in rows of tables
IVab. Identifying spatial patterns of symbols and numbers in a table
IVb1. Supplying operations to make equalities for specific numerical statements
IVb2. Supplying missing digits in specific statements of numerical equality
Symbol Recognition
Recognition of Patterns (Closure)
Number

(From Gagne, 1967)

The rules would vary depending on the nature of the number series involved and on the way in which the letters and subscripts were assigned to the numbers. If the problem were to find a formula for the sum of all the whole numbers from 1 to 100, two rules which might be produced are "Adding the first and last numbers in the series produces the same sum as adding the second and the next to the last or the third and the third from the last and so on. Also, the number of such sums is equal to the total amount of numbers divided by two if n is even." At the top is the higher order rule which puts together the rules found below it for getting a concise method for summing the series.

By ascertaining which subskills have been learned by students and which ones still need to be developed, the instructor would have a guide to structuring instruction which also enables him/her to diagnose student problems in learning the skill as well as his/her own problems as an instructor.

Gagne's approach to instruction emphasizes reinforcement as the means for implanting each subskill in the minds of learners. Once the lower levels of learning have been attained by the learner, integrating these parts into a concept, for instance, can also be accomplished with proper conditioning techniques and practice. It is here that one must consider the findings of Piagetian research in determining which concepts are attainable at a given cognitive level and which ones would be better postponed.

Gagne's approach is a "common-sense logic" approach rather than a psychological or a theoretical approach to the teaching of cognitive skills. It has been used most notably by Science - A Process Approach (AAAS Commission on Science Education, 1967) in a chart for teachers which indicates not only the topics and sequence of lessons within each topic but also the set of prerequisite relationships which may be presumed to exist among them. An example of a general hierarchical chart is the scope-and-sequence chart for grades one through six on the conservation of energy shown in Figure 5.

The mechanics of actually drawing out such a chart for every skill to be learned by children would be unnecessary drudgery. However, the charts can help us analyze the skills fifth and sixth graders are expected to learn so that we can subsequently understand the problems they are having, assess their mastery, and thereby facilitate their learning. Until we have a better understanding of the psychological processes underlying the learning of cognitive skills, this is a sensible way to proceed in the teaching of skills.

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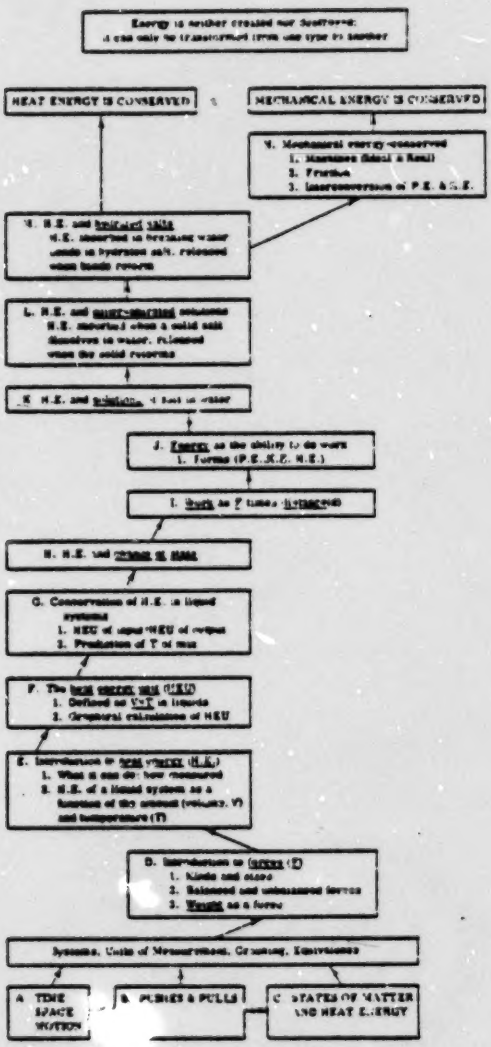
HEAT ENERGY IS CONSERVED
MECHANICAL ENERGY IS CONSERVED
A. TIME SPACE MOTION
B. PUSHES & PULLS
C. STATES OF MATTER AND HEAT ENERGY

Figure 5. Conservation of energy: scope and sequence for grades K-6 (From COPES Newsletter, Vol. 1, No. 1 [1976].

Verbal Information

David Ausubel's contribution to the field of cognition is in the area of verbal information whereas Gagne's was in intellectual or cognitive skills; Gagne (1974) contrasts these two as the "knowing that" as opposed to the "knowing how" of information. Ausubel proposes the use of "advance organizers" to facilitate the learning of verbal information. An advance organizer

consists of general, inclusive verbal information introduced before the specific new information to be learned. A review of the literature on advance organizers (Barnes and Clawson, 1975) indicates that this idea definitely has some merit.

An example of an advance organizer would be something like the following (the organizer is underlined).

> Man has evolved gradually to become the kind of creature we see today. An examination of fossil skulls dating back twenty million years, when "men" first appeared, to the present time shows an overall increase in brain size from 500-700 cubic centimeters to 1200-1300 cubic centimeters. His posture has changed from walking on all fours to walking on two feet with head more erect. This change also opened the way for changes in the human hand which was now free from walking to do other things. The development of an opposable thumb enabled man to grip things more firmly and with more precision. Thus, man began to form and use tools from stone or bone to improve his chances for survival.

It has been found that "comparative" advance organizers which explicitly point out differences and similarities between new material and already known material seem to be better than "expository" advance organizers, which present new ideas concisely and do not relate them to any previously learned material; both comparative and expository advance organizers are better than historical introductions in aiding recall of material (Ausubel and Fitzgerald, 1961). Steinbrink (1970) found advance organizers superior to organizers placed at the end of the text. Other advance organizers which appear to have value but have not been extensively researched are visuals such as pictures, maps, and graphs.

Two other methods of presentation which aid in recall of information are 1) meaningful coding of names and labels and 2) imagery. Individual facts such as names and labels may be efficiently coded by placing them within larger structures such as sentences (Rohwer and Lynch, 1966). Children aged 6 through 11 learned word pairs such as LION-HORSE with considerably

greater success when they were presented sentences like "The LION scares the HORSE" than when they were presented in conjunctive phrases such as "The LION and the HORSE."

Creating a mental picture has been shown to be a successful aid to remembering (Bower, 1971; Paivio, 1971; and Crovitz, 1970). For example, a person might enhance his/her memory of a series of events, objects, or people by imagining a street or room that connected the ideas for him/her. Techniques of this sort have been used for many years by professional memory experts. The human memory naturally works this way, and mentally coding by imagery may be beneficially employed. Often, this can be best done by suggesting the form of the imagery to the learner, rather than by providing an actual picture or diagram.

In summary, advance organizers, meaningful coding of names and labels, and imagery are three methods of presenting verbal information which facilitate recall. When presenting children with information which can be used later to solve problems, it is worthwhile to consider these methods for organizing the information.

Cognitive Strategies and Problem Solving

Cognitive strategies are internally organized capabilities which the learner uses to guide his/her own attending, learning, remembering, and thinking. When a novel problem is posed for a learner, s/he must bring to bear upon it previously learned information, previously developed intellectual skills; s/he must have a strategy to approach the new problem. Examples of strategies that people use for attacking new problems include 1) trying to remember the solution to a similar problem; 2) using trial and error; 3) using concrete examples; 4) keeping their eyes on the goal;

5) arranging things in ascending or descending order; and 6) rehearsing (primarily for memorizing) (Lecture at Stanford University by Lee J. Cronbach, Fall 1975). The efficacy of any of these strategies varies according to the kind of answer required and the amount of time available. If only a limited repertoire of cognitive strategies is available to students, their problem-solving capacities are also limited.

Torrace (1967) found that American fourth graders are less original in cognitive performance than are German, Samoan, or Australian children. He felt that this difference might be attributable to what is emphasized in American schools. Clearly, if American schools emphasize the use of the first cognitive strategy mentioned above to the exclusion of others, we would expect a drop in orginality. Whether or not this is the case, there are ways in which production of original thinking can be increased. They include: 1) reward original ideas; 2) free children from the threat of evaluation when they are engaged in the production of divergent ideas; 3) provide them with open-ended questions to work on; and 4) present them with controversial or paradoxical ideas. Brainstorming sessions with groups of children are contexts in which this kind of thinking can be facilitated.

An example of a program designed specifically for teaching cognitive strategies of problem solving to fourth and fifth graders is the Productive Thinking Program (Covington, Crutchfield, Davies, and Olton, 1972). In this program children were given a set of booklets providing "guided practice" in problem solving. Each booklet described a detective-type mystery problem for the child to solve. As the story unfolded, printed verbal instructions introduced certain strategies, one at a time, to the student. Examples of the strategies included were 1) how to generate many ideas, 2) how to evaluate

the relevance of ideas to fact, 3) how to look at a problem in new ways, 4) how to ask relevant questions, 5) how to become sensitive to useful clues, and 6) how to clarify the essentials of the problem. The students practiced such skills in connection with each problem and wrote down their ideas, questions, or suggestions for what should be done next. Results of studies using this method have shown substantial improvements in the problem-solving performances of fourth and fifth grade children, when tested on a set of entirely new problems of varied content. This approach and results of this program have been described by Olton and Crutchfield (1969).

Summary

In terms of cognitive development, the majority of fifth and sixth graders are either near the end of the stage of concrete operations or at the beginning of formal operations. Those at the concrete level are able to deal mentally with things from their own real, physical world somewhat independent of physical manipulation. However, they are not able to mentally deal with concepts which have no physical referents. This skill is in the cognitive repertoire of adolescents who have attained some aspects of formal operations. Thus, the problem solving situations provided for fifth and sixth graders can involve abstract thinking but, at least initially, should deal with phenomena from the real world. Abstracting ideas and using them to make general statements may be a desirable ability, but it simply cannot be expected from all children at this age. Adolescents in the stage of formal operations enjoy using their newly acquired abstract, logical abilities. It might also be worthwhile to expose these children and those in the concrete operational level to problems of a social or artistic nature for which the logico-mathematical levels of Piagetian cognitive development do not readily apply.

The problems that can be given to fifth and sixth graders typically require cognitive skills of a complex nature, and there may be a need to give students instruction in specific areas. Both a careful consideration of what subskills are involved and an efficient way of assessing student abilities are necessary in designing lessons and experiences for children. Adults need to judge accurately what students are able to do (keeping Piaget in mind, for instance) as well as how much time students can reasonably be expected to spend on learning a skill.

Information to be learned or used in problem solving can be made more memorable if it is presented with advance organizers, meaningful coding and/or imagery. Pictures, charts and graphs may also provide cogent visual organizers for students to use when trying to conceptualize and solve new problems.

Lastly, special effort needs to go into creating situations which encourage the use of appropriate cognitive strategies for new situations. In addition to the convergent thinking skills of remembering and comprehension, children need to be encouraged to produce divergent ideas which open up new solutions to problems not solvable by ideas or strategies that may have been successful in their previous school experiences. Brainstorming generates new ideas and strategies, and students should have some time when they can freely express themselves without fear of evaluation from others. The difference between brainstorming an idea and later thinking critically about the ideas produced should be made clear to students by emphasizing the different but equally valuable outcomes of these two kinds of thinking.

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